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I, ANNA MAIJA MADL, ACTING TEAM LEADER EXAMINATION SUPPORT & SALES hereby certify that annexed is a true copy of the Provisional specification in connection with Application No. PP 7407 for a patent by SOLA INTERNATIONAL HOLDINGS LTD filed on 30 November 1998.

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Twenty-second day of December 1999

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PROVISIONAL SPECIFICATION

Invention Title: **Customised coated lens**

The invention is described in the following statement:

FHPMELC698334005.6

CUSTOMISED COATED LENS

The present invention relates to optical articles bearing a coating which displays superior uniformity of colour.

The optical articles according to the present invention are preferably employed in the preparation of articles such as optical lenses, including spectacle lenses, including sunglass lenses, visors, shields, glass sheets, protective screens, and the like.

Sunglasses generally serve to attenuate transmitted light, but aside from the level of light transmittance, there are other features that distinguish different sunglass lenses, such as material, transmitted colour, scratch resistance, reduction of side glare, ultra-violet transmittance, cosmetic appearance etc. Coatings, e.g thin films, may be applied to enhance the performance of sunglass lenses. Such coatings include scratch resistant coatings, hydrophobic coatings for easier cleaning, anti-reflection coatings for reducing side glare or "mirror" (or "interference") coatings for producing fashionable lens colours. General purpose sunglass lenses should meet certain standard specifications, including luminous transmittance, traffic signal recognition and UV transmittance (e.g. ANSI Z80.1-1995).

Anti-reflection coatings are commonly deposited on ophthalmic and sunglass lenses in order to minimise spurious reflections, which both detract from the wearer's vision and are also cosmetically unpleasing. These coatings commonly consist of multilayer, dielectric films of thicknesses chosen so that interference effects cause destructive cancellation of reflections over most of the visible spectrum. Due to cost and process control factors, these coatings are typically constructed from four to six layers, and exhibit a very weak, but visible residual reflection.

When mirror and anti-reflection coatings are deposited on curved substrates (such as ophthalmic lenses), geometrical factors result in the coating thickness being non-uniform and varying systematically over the surface of the

lens. The colour (and brightness) of the residual reflection changes from the centre to the edge of the lens, an effect referred to as "colour rolloff." Normally the colour rolloff is barely noticeable and cosmetically, the lenses are considered to be acceptable. However, for very highly curved lenses, the colour rolloff is particularly noticeable and is generally considered to be unsatisfactory.

One method proposed in the prior art to reduce colour rolloff is to mount the substrate on a "planetary rotation" stage, which spins the lens about its own axis at the same time that it rotates about another central axis. The result of the complex substrate motion in the deposition chamber is that the flux of coating material is more evenly distributed over the surface of the lens, resulting in a coating that is more uniform over the substrate than would otherwise be the case. Planetary rotation is not the only option - any substrate motion at all will tend to reduce coating thickness non-uniformities. Unfortunately, implementing such substrate movement in the deposition chamber necessary involves mechanical complexity and a likely decrease in the total number of substrates that can be coated simultaneously in the apparatus, which is a severe disadvantage in a commercial production process.

It would accordingly be a significant advance in the art if ophthalmic lenses could be provided with a coating or coatings of general applicability which could reduce the phenomenon of "colour rolloff", but without the need for "planetary rotation" apparatus.

Accordingly, it is an object of the present invention to overcome, or at least alleviate, one or more of the difficulties or deficiencies related to the prior art.

Accordingly, in a first aspect of the present invention there is provided an optical lens including

a lens element including a surface of high curvature; and

a coating exhibiting a visually substantially uniform reflectance from the centre to the edge of the lens element.

By the term "surface of high curvature", we mean a surface having a base

curve approximately 6 Dioptres (D) or greater, preferably 6 D to 20 D, more preferably approximately 8 D to 16 D.

The visual appearance of the lens in reflected light can be characterised by a "brightness" corresponding primarily to the luminous intensity of the reflected light; and two chromatic attributes, corresponding to the "hue" and "saturation" of the colour. ("The Measurement of Appearance", 2nd ed., R.S. Hunter and R.W. Harold, Wiley, New York, 1987). By "visually substantially uniform reflectance" we mean that the brightness, hue and saturation vary across the surface of the lens in a manner that is either imperceptible or generally acceptable. Perceived variations in appearance can be quantified by calculating "CMC colour differences." A CMC colour difference of one is at the limit of perceptibility. We have found that this is too stringent a tolerance for the ophthalmic industry, and have observed that colour differences of up to 5-10 may exist across a lens that has an acceptably uniform appearance.

It is well-known that the reflectance of thin film coatings tends to vary with the angle of the incident light. When we speak of the reflectance from the lens we imply the reflectance of light incident at angles of 0 to approximately 30 degrees to the normal to the surface of the lens, as would typically be the case for the reflected light seen by an observer standing directly in front of a person wearing the coated lenses as spectacles.

It will be understood that regardless of the deposition method used (eg. evaporative, sputtered etc), coatings deposited on curved substrates that are not subjected to complex motion tend to exhibit thickness non-uniformity, with the coating thickness typically greatest where the surface of the substrate is most normal to the incident flux of particles, and thinner where the surface faces the flux at an angle. For ophthalmic lenses, which are normally mounted with their centres facing the particle source, this means a coating that is thickest in the middle and that becomes thinner at the edge of the lens.

It will be recognised by those familiar with the art and theory of thin films that when a coating becomes systematically thinner in this way, its reflectance

spectrum shifts toward the blue side of the spectrum. The reflectance spectrum of a prior art lens coated with a typical commercial anti-reflection coating (for light at normal incidence) is shown in Figure 1.

The reflectance is low in the middle of the visible spectrum (roughly 380-780 nm), but increases sharply for shorter and longer wavelengths. Toward the edge of the lens, where the total coating thickness reduces due to the curvature of the lens as described above, the spectrum shifts to the left as shown, with the consequence that the higher reflectance "red tail" seen in Figure 1 moves further into the region of spectral sensitivity of the human eye. In this particular example, the lens is not greatly curved (6 Dioptres). For a more highly curved lens, the spectral shift would be more substantial. A significant reddening of the coating would be seen on highly curved substrates.

In contrast, the uniform reflectance coating according to the present invention provides a low, substantially uniform appearance from the centre to the edge of the lens element.

This may be achieved, inter alia, by providing a uniform reflectance coating which at the centre of the lens exhibits low photopic reflectance at longer wavelengths, e.g. above approximately 620 nm, and low reflectance in the vicinity of 555 nm where the eye is most sensitive.

The uniform reflectance coating may exhibit a substantially constant photopic reflectance in the wavelength range of approximately 620 to 880 nm, the photopic reflectance preferably being less than approximately 1.5%.

The uniform reflectance coating may, for example, exhibit a reflected colour difference from the centre to the edge of the lens of less than approximately 10 CMC colour difference units.

The uniform reflectance coating may additionally function as an anti-reflective coating. The uniform reflectance coating may alternatively or in addition function as a light absorbing, or tint coating, in which case it may also have an

asymmetric reflectance, such that from the wearer's side of the lens the coating is anti-reflective.

In accordance with the present invention, one or both surfaces of an optical lens may be coated with the uniform reflectance coating.

The lens element may be either optically clear or tinted (light absorbing), such as a sunglass lens, ophthalmic lens element, visor or the like. A sunglass lens is preferred.

By the term "ophthalmic lens element", as used herein, we mean all forms of individual refractive optical bodies employed in the ophthalmic arts, including, but not limited to, lenses, lens wafers and semi-finished lens blanks requiring further finishing to a particular patient's prescription.

In a preferred aspect, the lens element may be of generally ovaline shape and is located on the surface of a sphere whose radius of curvature corresponds to 11 D or above, a toroid where the horizontal radius of curvature corresponds to 11 D or above, or a surface where the radius of curvature changes across at least one section of the lens aperture.

The lens element may be of the type described in International Patent Application PCT/AU98/00872 "Spectacle Frames" to Applicants, the entire disclosure of which is incorporated herein by reference; or in Australian Provisional Patent Application PP4748 "Optical Lens" to Applicants, the entire disclosure of which is incorporated herein by reference.

Where the lens element is an ophthalmic lens element, the ophthalmic lenses may be formed from a variety of different lens materials, and particularly from a number of different polymeric plastic resins. A common ophthalmic lens material is diethylene glycol bis (allyl carbonate). Lens materials with higher refractive indices are now growing in popularity. One such material is a CR39 (PPG Industries). Other high index lens materials are based on acrylic or allylic versions of bisphenols or allyl phthalates and the like. Other examples of lens

materials that may be suitable for use with the invention include other acrylics, other allylics, styrenics, polycarbonates, vinylics, polyesters and the like.

In a preferred aspect, the uniform reflectance coating may be a multi-layer coating. The uniform reflectance coating may include a plurality of layers, the thickness and/or number of which being selected to reduce the phenomenon of "colour rolloff". The uniform reflectance coating may also provide an interference effect, e.g. an anti-reflective or mirror effect.

Preferably the uniform reflectance coating includes a plurality of low and high refractive index layers, wherein the thickness and/or number of the respective layers are selected to provide a desired reflectance; the reflectance not varying substantially in visual appearance when applied to a surface of a lens of high curvature.

More preferably, the uniform reflectance coating exhibits a low photopic reflectance at longer wavelengths, e.g. above approximately 620 nm.

The number and/or thickness of the layers may be selected utilising suitable computer software.

The low and high refractive index layers may be formed from any suitable material. The low and high refractive index layers may be formed of a dielectric material. Preferably the dielectric layers may be formed from metal oxides, fluorides or nitrides. Metal oxides which may be used for forming transparent layers include one or more of SiO, SiO_2, ZrO_2, Al_2O_3, TiO, TiO_2, Ti_2O_3, Y_2O_3, Yb_2O_3, MgO, Pr_2O_3, Ta_2O_5, CeO_2 and HfO_2. Fluorides which may be used include one or more of MgF_2, AlF_3, BaF_2, CaF_2, Na_3AlF_6, Ta_2O_5, and $Na_5Al_3Fl_{14}$. Suitable nitrides include Si_3N_4 and AlN.

A silica (SiO_2) or magnesium fluoride (MgF2) material is preferred for the low index layers.

A combination of titanium and praseodymium oxide (TiO_2 + Pr_2O_3) is

preferred for the high index layers. Such a combination may have a refractive index at 500 nm of approximately 2.15.

In a preferred form, the uniform reflectance coating may include a total of 4 to 6 alternating high and low index layers, preferably 4 to 6 alternating layers.

The optical lens according to the present invention may further include one or more additional coatings. Accordingly in a further aspect of the present invention there is provided a multi-coated optical lens including

a lens element including a surface of high curvature; and

a coating on a surface of the lens element exhibiting a visually substantially uniform reflectance from the centre to the edge of the lens element; and

one or more secondary coatings which provide a desirable optical and/or mechanical property to the optical article.

The secondary coatings may overlay or underlay the uniform reflectance coating or be applied to a second surface of the lens element.

The secondary coatings may be of any suitable type. The secondary coatings may be one or more of an anti-reflective, abrasion resistant, or impact-resistant coating. An abrasion-resistant coating is preferred. The combination of an abrasion resistant coating and an anti-reflective coating is particularly preferred.

An abrasion-resistant (hard) coating including an organosilicone resin is preferred. A typical organosilicone resin that is suitable for use in the present invention has a composition comprising one or more of the following:

1) organosilane compounds with functional and/or non-functional groups such as glycidoxypropyl trimethoxy silane;
2) co-reactants for functional groups of functional organosilanes, such as organic epoxies, amines, organic acids, organic anhydrides, imines, amides, ketamines, acrylics, and isocyanates; colloidal silica, sols and/or metal and non-metal oxide sols; catalysts for silanol condensation, such as dibutylin dilaurate;

3) solvents such as water, alcohols, and ketones;

4) other additives, such as fillers.

Abrasion resistant coats of acrylic, urethane, melamine, and the like may also be used. These materials, however, frequently do not have the good abrasion resistant properties of organo-silicone hard coatings.

The abrasion-resistant (hard) coating may be coated by conventional methods such as dip coating, spray coating, spin coating, flow coating and the like or by newer methods such as Plasma Enhanced Chemical Vapour Deposition. Coating thicknesses of between approximately 0.5 and 10 microns are preferred for abrasion and other properties.

The secondary abrasion resistant coating may be applied to the front and/or rear lens surfaces. The abrasion resistant coating may be of the type described in United States Patent 4,954,591 to the Applicants, the entire disclosure of which is incorporated herein by reference.

In a preferred aspect of the present invention the secondary coating may be an anti-reflective coating applied to the opposite surface of the lens element. In this form, the lens is anti-reflective as viewed from the rear, or substrate side.

The anti-reflective coating may be of any suitable type. The anti-reflective coating may be a multi-layer coating. The anti-reflective coating may include overlapping dielectric layers. Alternatively the anti-reflective coating may include overlapping metal and dielectric layers.

The dielectric layers may be selected from one or more of the following: SiO, SiO_2, ZrO_2, Al_2O_3, TiO, TiO_2, Ti_2O_3, Pr_2O_3, Y_2O_3, Yb_2O_3, MgO, Ta_2O_5, CeO_2 and HfO_2, MgF_2, AlF_3, BaF_2, CaF_2, Na_3AlF_6, Ta_2O_5 and $Na_5Al_3Fl_{14}$; and Si_3N_4 and AlN.

The metallic layers may be formed from a metallic material selected from the metals, metal oxides or nitrides of one or more of Niobium (Nb), Chromium

(Cr), Tungsten (W), Tantalum (Ta), Tin (Sn), Palladium (Pd), Nickel (Ni) or Titanium (Ti).

The anti-reflective coating may be of the type described in International Patent Application PCT/AU98/00868 to Applicants, the entire disclosure of which is incorporated herein by reference.

In a further preferred aspect, one or both surfaces of the optical article may be subjected to a surface treatment to improve bondability and/or compatibility of the uniform reflectance and/or secondary coating. The surface treatment may be selected from one or more of the group consisting of plasma discharge, corona discharge, glow discharge, ionising radiation, UV radiation, flame treatment and laser, preferably excimer laser treatment. A plasma discharge treatment is preferred. The surface treatment, alternatively or in addition, may include incorporating another bonding layer, for example a layer including a metal or metal compound selected from the group consisting of one or more of Chromium, Nickel, Tin, Palladium, Silicon, and/or oxides thereof.

The optical article may be a sunglass lens of the wrap-around or visor type, for example of the type described in International Patent Application PCT/AU97/00188 "Improved Single Vision Lens" to Applicants, the entire disclosure of which is incorporated herein by reference.

In a further aspect of the present invention, there is provided a method for preparing a coated optical lens, which method includes

providing

a lens element including a surface of high curvature; and

a coating exhibiting a visually substantially uniform reflectance from the centre to the edge of the lens element; and

depositing the coating on a surface of the lens element.

Preferably the uniform reflectance coating is applied to both surfaces of the lens element.

According to the present invention it has been found that, following the method mentioned above, it is possible to achieve a relatively thin, uniform reflectance coating with consequent advantages in both optical and mechanical properties.

Preferably the method further includes

providing

a lens element including a surface of high curvature,

a high refractive index material , and

a low refractive index material;

depositing overlapping layers of high and low refractive index material on a surface of the optical lens element, the number and/or thickness of the respective layers being selected to provide a desired substantially uniform reflectance across the surface the lens element and to provide a desired interference effect, preferably an anti-reflective effect or mirror effect.

In a preferred aspect the high and low refractive index materials, preferably Pr_2O_3/TiO_2 and SiO_2, are deposited as alternating layers.

The deposition step may be a vacuum deposition step. The deposition step may be conducted in a coating apparatus. A box coater or sputter coater may be used.

The uniform reflectance coating may preferably be formed on the surfaces of the substrate according to the process and the box coaters as described in the Italian Patent No. 1.244.374 the entire disclosure of which is incorporated herein by reference.

In accordance with said method, the various layers of the uniform reflectance coating may be deposited in subsequent steps utilising a vacuum evaporation technique and exposing the growing layers to a bombardment of a beam of ions of inert gas.

Moreover, in accordance with the preferred method, the deposition of the

layers may be achieved at a low temperature (generally below 80°C), using an ion beam having a medium intensity (meaning the average number of ions that reach the substrate) included between approximately 30 and 100 μA/cm2 and the energy included between approximately 50 and 100 eV.

Further characteristics and advantages of the present invention will be apparent from the following description of drawings and examples of embodiments of the present invention, given as indicative but not restrictive.

In the figures:

Figure 1 illustrates a measured reflectance spectrum (for light at normal incidence) of a lens coated on both sides with a known multilayer, anti-reflection coating.

Figure 2 illustrates a measured reflectance spectrum (for light at normal incidence) of a lens coated on both sides with a multilayer, anti-reflection coating corresponding to the present invention.

EXAMPLE 1

Table 1 shows the optical design for an anti-reflection coating that is robust to colour rolloff on highly curved substrates. As seen in Figure 2, this coating has been specifically designed to exhibit much lower reflectance at longer wavelengths at the centre of the lens. For a highly curved substrate, where the coating reduces in thickness toward the edge, the edges will not exhibit the same degree of reddening as with an ordinary anti-reflection coating, because the infra-red portion of the coating reflectance that moves into the eye's range of sensitivity has intentionally low reflectance. The result is a coating that demonstrates substantially improved colour uniformity on highly curved substrates, without the requirement for additional substrate motion during deposition.

TABLE 1

Optical design for an anti-reflection coating for highly curved lenses

Layer	Thickness (nm)
Hard resin substrate	
Pr2O3/TiO2 (n(500 nm) =2.15)	15.9
SiO2	32.5
Pr2O3/TiO2 (n(500 nm) =2.15)	147
SiO2	102

It will be understood that the invention disclosed and defined in this specification extends to all alternative combinations of two or more of the individual features mentioned or evident from the text or drawings. All of these different combinations constitute various alternative aspects of the invention.

SOLA INTERNATIONAL HOLDINGS LTD
By their Registered Patent Attorneys
Freehills Patent Attorneys 30 November 1998

FIGURE 1

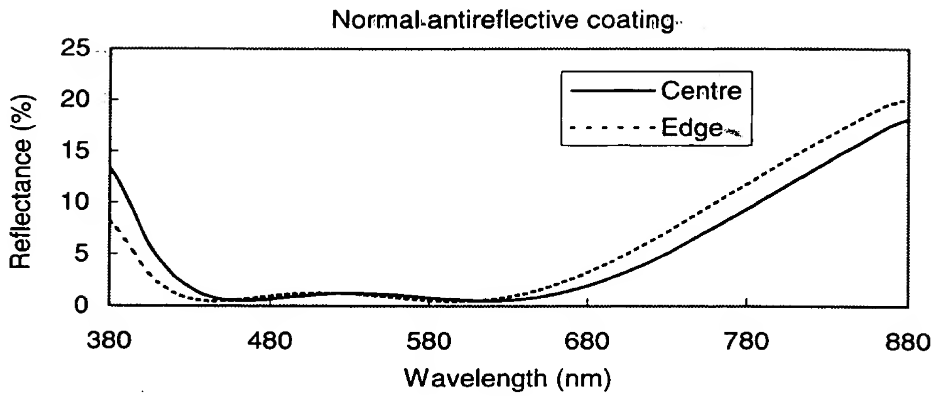
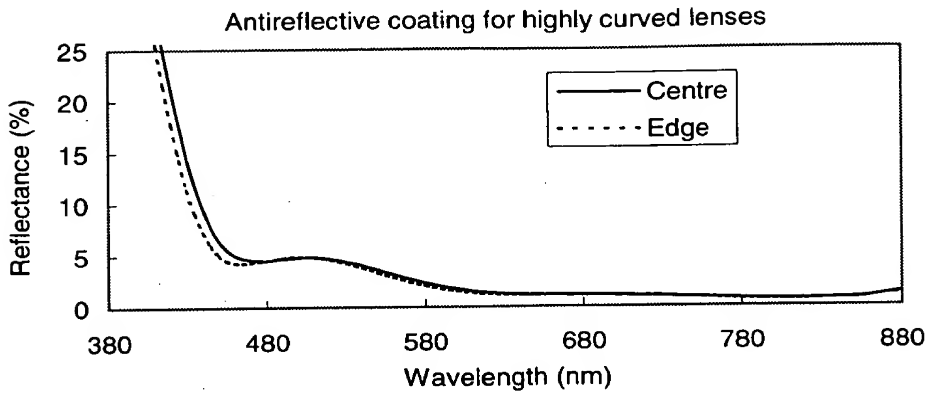

Normal antireflective coating
Reflectance (%)
25
20
15
10
5
0
Centre
Edge
380
480
580
680
780
880
Wavelength (nm)

FIGURE 2


Antireflective coating for highly curved lenses
Reflectance (%)
25
20
15
10
5
0
380
480
580
680
780
880
Wavelength (nm)
Centre
Edge